Duration Uncertainty Based On Actual Performance Lessons Learned

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Agenda

- Introduction
- Duration Ratio Method Summary
- Duration Ratio Method on a NASA Project
- Lessons Learned
- Recommendations to NASA Scheduling Community

Introduction

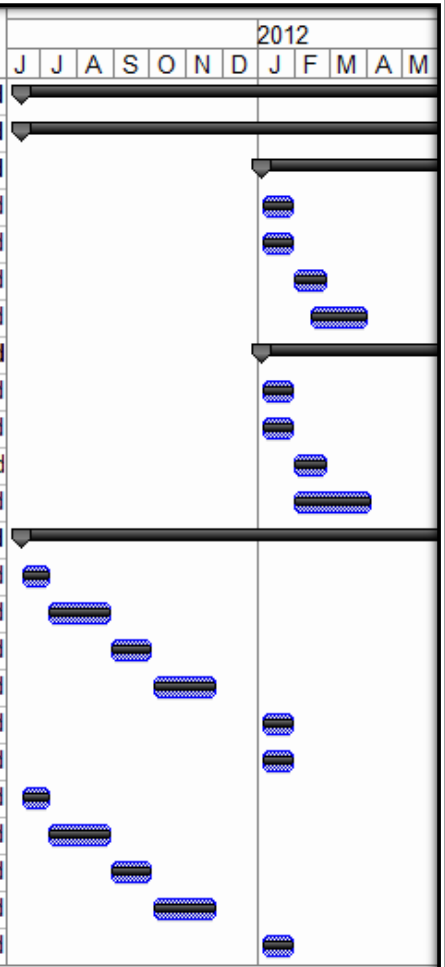
- The authors have used the Duration Ratio Method (DRM) to characterize the schedule duration uncertainty for the schedule risk analysis (SRA) and joint confidence level (JCL) analysis of a major NASA project
- DRM uses actual performance data at the task level of the project integrated master schedule (IMS) to develop schedule uncertainty distributions for Monte Carlo simulations
- This presentation examines lessons learned from applying the technique to a NASA project

Duration Ratio Method Summary

- Along with discrete risk events, schedule duration uncertainty is a significant contributor to schedule growth
- Bounding duration uncertainty is important for a sound SRA
- The project (or contractor) IMS contains an objective, performance-based source of duration uncertainty: actual and baseline durations at the task level for discrete work

Actual vs. Baseline Durations from IMS

Task Name	Actual Duration	Baseline Duration
Develop Central / Local EM (CLEM) Subsystem	**260 d**	**695 d**
CM Network / Server / DB / ODS	**286.32 d**	**578 d**
Perform COTS Implementation for Central / Local CM - IDE (Inc 1)	**129.41 d**	**293 d**
Perform COTS Evaluation for Local CM - IDE (Inc 1)	19 d	19 d
Perform COTS Evaluation for Central CM - IDE (Inc 1)	19 d	19 d
Perform COTS Evaluation for Central / Local CM - IDE (Inc 1)	20 d	6 d
Develop Preliminary Design for Central / Local CM - IDE (Inc 1)	35 d	25 d
Perform COTS Implementation for Central / Local CM - IDE (Inc 2)	**126.33 d**	**311 d**
Perform COTS Evaluation for Local CM - IDE (Inc 2)	19 d	19 d
Perform COTS Evaluation for Central CM - IDE (Inc 2)	19 d	19 d
Perform COTS Evaluation for Central / Local CM - IDE (Inc 2)	20 d	11 d
Develop Preliminary Design for Central / Local CM - IDE (Inc 2)	46 d	44 d
Perform COTS Implementation for Central / Local Online Doc Server	**304.54 d**	**425 d**
Plan COTS Trade Studies for Local Online Doc Server	15 d	15 d
Perform COTS Trade Studies for Local Online Doc Server	37 d	15 d
Review COTS Trade Studies for Local Online Doc Server	24 d	10 d
Release COTS Trade Studies for Local Online Doc Server	38 d	10 d
Define COTS Requirements for Local Online Doc Server	19 d	15 d
Finalize COTS Selection for Local Online Doc Server	19 d	20 d
Plan COTS Trade Studies for Central Online Doc Server	15 d	15 d
Perform COTS Trade Studies for Central Online Doc Server	37 d	15 d
Review COTS Trade Studies for Central Online Doc Server	24 d	10 d
Release COTS Trade Studies for Central Online Doc Server	38 d	10 d
Define COTS Requirements for Central Online Doc Server	19 d	15 d



Duration Ratio Method Formula

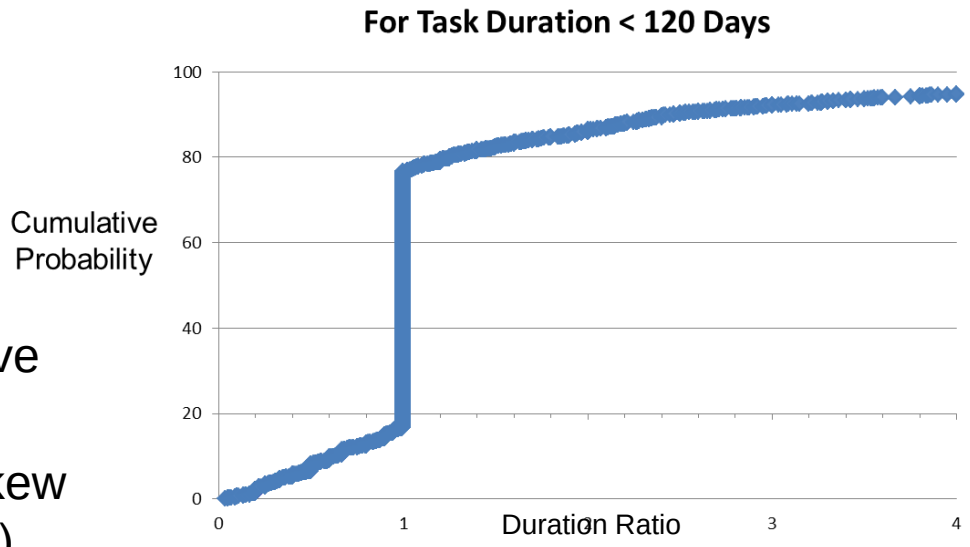
Duration Ratio

	Formula:	*Example:*
Duration Ratio	$= \frac{\text{Actual Activity Duration}}{\text{Baseline Activity Duration}}$	$1.50 = \frac{6 \text{ days}}{4 \text{ days}}$

- Planned and actual task durations are factual, objective and performance-based
- Uncertainty is based on the actual project and performing organization
- Focus is on discrete activities – milestones, summary activities and level of effort-type activities are not included

Duration Ratio Method Steps

1. Extract completed activities from IMS file
2. Identify discrete activities: filter out summary tasks, LOE and milestones
3. Calculate Duration Ratios for activities
4. Sort in ascending order
5. Calculate percentages for S curve
6. Examine/remove outliers and anomalies that may artificially skew results (i.e. “middle 80% or 90%)
7. Segment data to reduce variance (e.g. <21 days, 21 - <50 days, >50 days)



Duration Ratio Method on a NASA Project

- DRM was used to characterize the schedule uncertainty on an Independent Program Assessment (IPA) of an actual NASA project at PDR and CDR
  - The NASA project office oversees a prime contractor on a major software system development and deployment
  - The prime has experienced significant cost, schedule, and technical difficulties resulting in multiple replans
  - At PDR the IPAO PAG used the project's schedule analysis and developed duration ratio-based schedule uncertainty
  - At CDR PAG developed a new schedule analysis model due to programmatic and technical changes and updated the schedule uncertainty with new duration ratios
    - Note: The CDR assessment became a Step 2 process late in the assessment and remains open

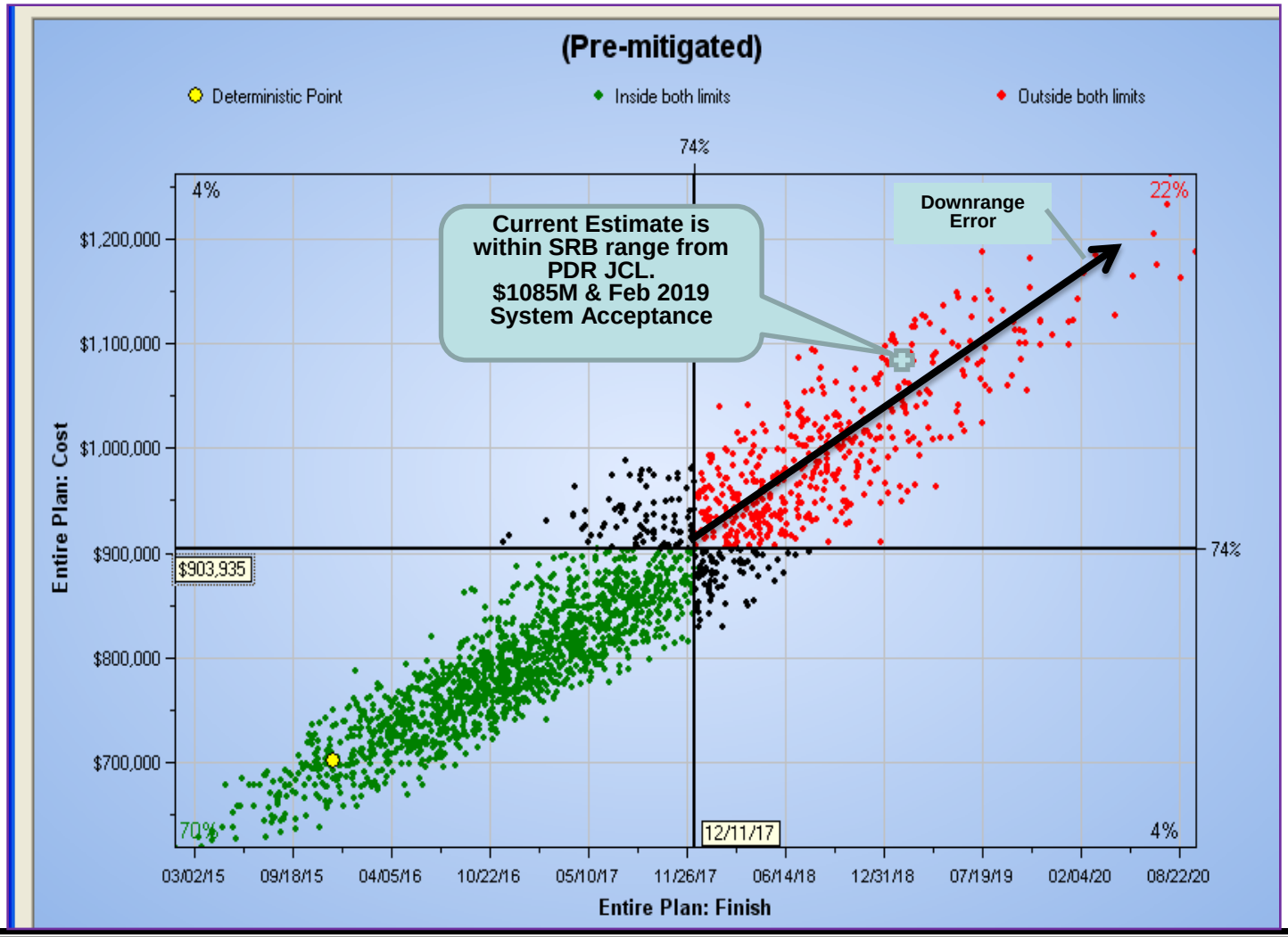
Duration Ratio Method on a NASA Project

- At PDR, duration ratios were segmented into three categories based on actual performance since SRR, using the “middle 80-90%” results
  - < 21 days duration
  - 21 – 50 days duration
  - > 50 days duration
- At CDR, duration ratios were also segment into three categories using the “middle 80-90%” results
- Along with the discrete risks assessed by the SRB, the PDR and preliminary CDR SRA results appear on the next page

DRM on a NASA Project: SRA Results Comparisons at PDR and CDR

- At PDR, the System Acceptance milestone dates were:
  - Proposed Management Agreement — March 2017
  - Proposed Agency Baseline Commitment — June 2017
  - Prime Contractor's Current Forecast — December 2015
  - Project's 70% SRA Results — May 2017
  - PAG/SRB 70% SRA Results (duration ratio-based) — October 2017
- At CDR, the System Acceptance milestone dates were:
  - Management Agreement — March 2017
  - Agency Baseline Commitment — June 2017
  - Prime Contractor's Forecast — September 2016
  - PAG/SRB 70% SRA Results (duration ratio-based) — February 2018
- As of June 2014, the System Acceptance milestone dates are:
  - Prime Contractor's Proposed Rebaseline — May 2018
  - Project's Risk-Adjusted Estimate — February 2019

Project's Current Estimates Are Within SRB's Predicted Range



Lessons Learned

- Lessons Learned from applying the Duration Ratio Method on an actual NASA project IPA:
  - Remove LOE, summary and selected discrete tasks from the analysis
  - Remove outliers to reduce bias in uncertainty
  - Segment uncertainty bounds to reduce variance
  - Simplify cumulative distributions to save time
  - Use historic duration time frames that make sense
  - Early life cycle interim baselines support duration ratios for PDR
  - Duration ratio quality depends on schedule baseline control
  - Explain Duration Ratio Method to SRB members

Lesson Learned #1: Remove LOE, Summary and Selected Discrete Tasks from Analysis

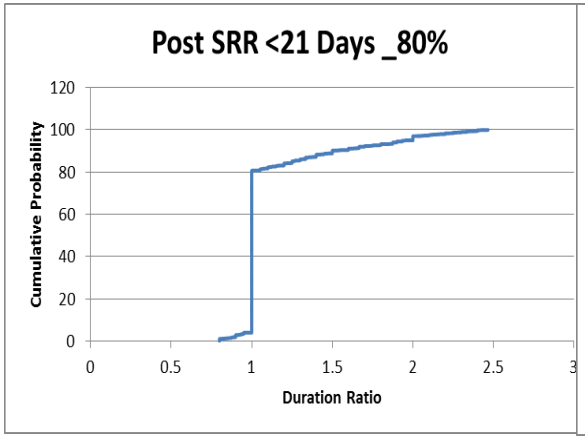
- Duration Ratios only makes sense for tasks associated with discrete, measurable work
- LOE tasks should be removed from the analysis since actual duration = baseline planned duration and the ratio always equals 1.00
- Summary level tasks are not needed since their lower level children tasks are already included in the analysis
- Some routine, administrative, and non-developmental tasks may be excluded from the analysis such as documentation preparation, status meetings, and project support activities

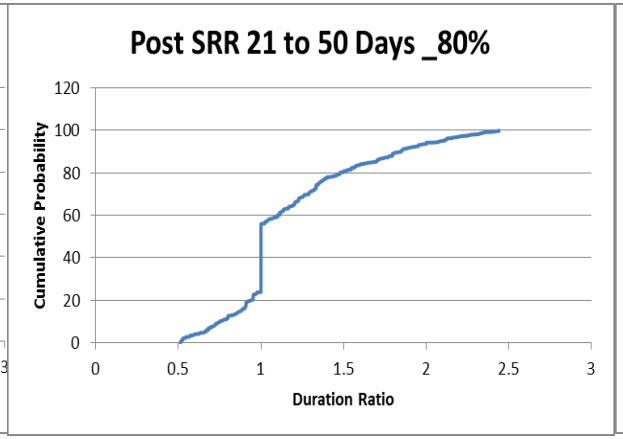
Lesson Learned #2: Remove Outliers to Reduce Bias

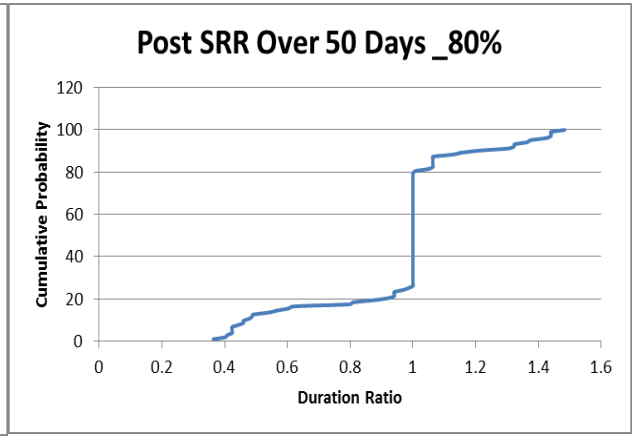
- The IMS may contain outlier duration ratios which could skew duration ratio distributions:
  - A high actual duration relative to a low baseline duration (e.g. 100 day actual / 2 baseline = 50 duration ratio)
  - A low actual duration relative to a high baseline duration (e.g. 5 day actual / 100 day baseline = .05
- These situations should be researched with the project for accuracy, realism, or other reason and a judgment call made on retention or removal
- Narrow the data set to the “middle 80% or 90%” of the duration ratio results to normalize the results

Lesson Learned #3: Segment Uncertainty Bounds to Reduce Variance

- Schedule uncertainty can be bounded, or categorized, using duration ratio statistics
- Therefore, three categories of uncertainty bounds were developed based on middle 80% of data for baseline duration of
  - < 21 Days
  - 21 – 50 Days
  - > 50 Days

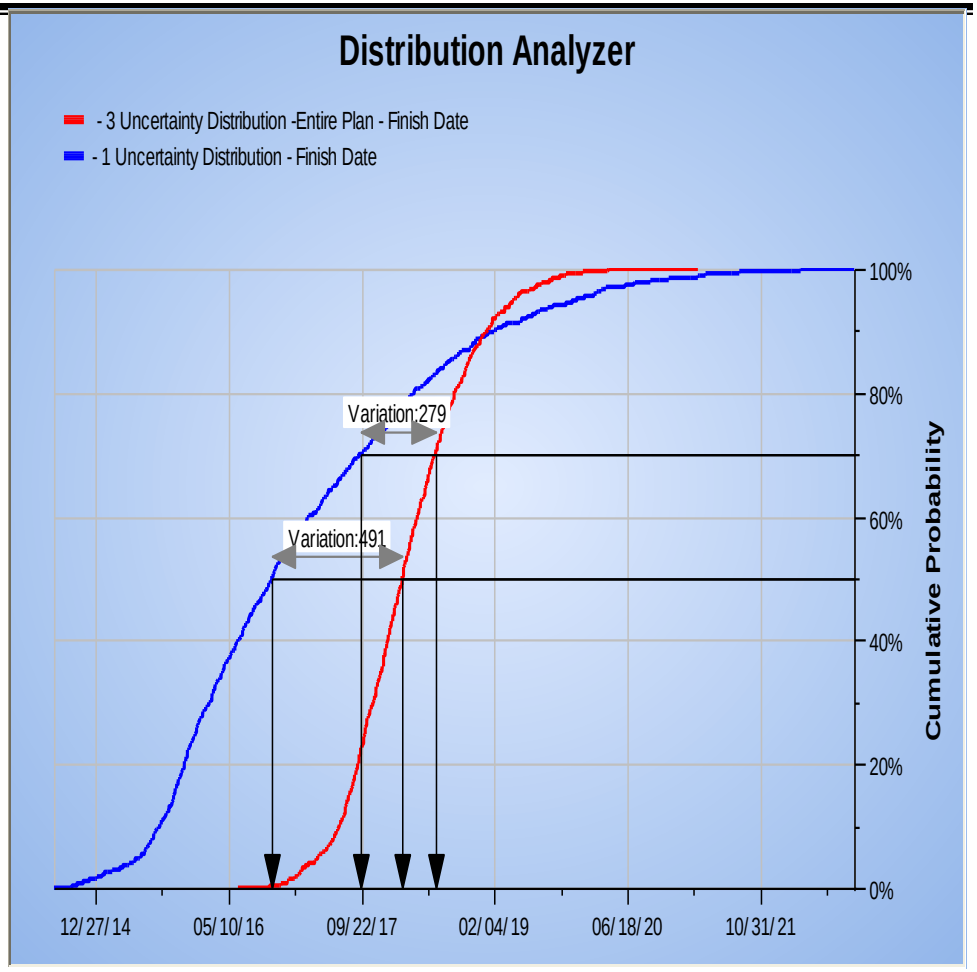






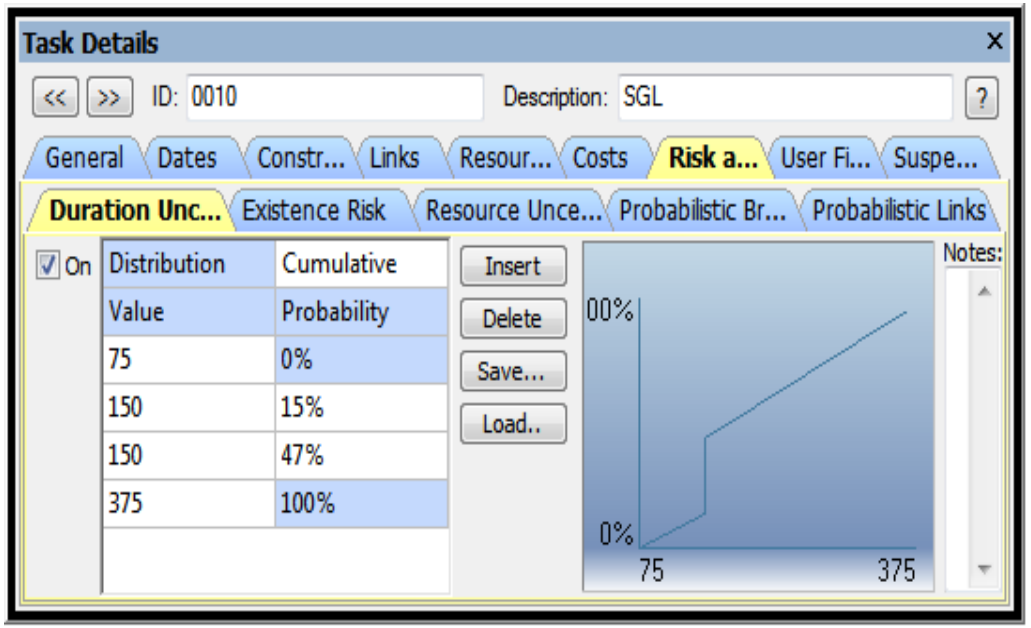
Comparing Uncertainty Distributions

- Sample results comparing uncertainty distributions using:
  - One uncertainty distribution
  - 3 segmented uncertainty distributions
- Segmentation of uncertainty bounds reduces variance
- Evaluate alternative ways of segmenting durations and Duration Ratios: WBS, phase, element or subsystem, integration & test, etc.



Lesson Learned #4: Simplify Cumulative Distributions to Save Time

- Primavera Risk Analysis (PRA), allows user to input uncertainty as a cumulative distribution function (CDF) as well as some pre-defined probability distribution functions (PDFs)
- Since IMS based duration uncertainty does not conform to any known PDFs, one can only work with tools that allow user to input CDFs
- Simplifying duration uncertainty with simple 4 point ranges can save time in preparing the SRA



Lesson Learned #5: Use Historic Duration Time Frames That Make Sense

- Analysts should examine the factors that affected the schedule so far to identify whether the entire duration history or selected segments best represent duration uncertainty in the future
- Factors to examine include: realism of schedule estimates, configuration changes, management changes, productivity assumptions, realized risks, or major replans/rebaselines
- Also consider phase transitions. For example, actual schedule performance in manufacturing may or may not an appropriate basis for testing phase schedule uncertainty

Lesson Learned #6: Early Life Cycle Interim Baselines Support Duration Ratios for PDR

- While NPR 7120.5E requires an IMS baseline at PDR, actual vs. baseline duration history may be available prior to PDR when:
  - The project establishes interim schedule baselines prior to PDR (e.g. Goddard requires a formulation schedule baseline at MCR)
  - Prime contract-driven projects that begin in Phase A or B normally require an earned value baseline (and supporting schedule baseline) at IBR

Lesson Learned #7: Duration Ratio Quality Depends on Schedule Baseline Control

- Baseline integrity must be maintained at the task level of the IMS for credible duration ratios
- Organizations (NASA centers, contractors, universities) may have different processes for controlling the schedule baseline – or none at all
- Schedule analysts must understand schedule baseline control methods as part of independent schedule assessment
- Effect of replans/rebaselines

Lesson Learned #8: Explain Duration Ratio Method to SRB Members

- Explain to SRB members the difference between the effect of duration uncertainty and impact of discrete risk events on the SRA results to avoid “double-counting” of risk

Recommendations To NASA Scheduling Community

- NASA to establish an IMS data repository similar to the ONCE database.
- Conduct or fund research on schedule duration ratio across multiple projects and life cycle phases to establish realistic 4-point uncertainty distributions.